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RESEARCH MEMORANDUM

AN INVESTIGATION OF THE SPIN AND RECOVERY CHARACTERISTICS OF A $\frac{1}{25}$-SCALE MODEL OF THE DOUGLAS D-558-II AIRPLANE

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AN INVESTIGATION OF THE SPIN AND RECOVERY CHARACTERISTICS OF A $\frac{1}{25}$-SCALE MODEL OF THE DOUGLAS D-558-II AIRPLANE

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SUMMARY

An investigation of the spin and recovery characteristics of a $\frac{1}{25}$-scale model of the Douglas D-558-II airplane has been conducted in the Langley 20-foot free-spinning tunnel. The effects of control settings and movements upon the erect and inverted spin and recovery characteristics of the model were determined for the model in the normal design gross weight loading. The effects of varying the stabilizer incidence, extending slats, and removing the stall-control vanes were also determined. Tests were also performed to determine the effects of ventral fins on the spin and recovery characteristics and to determine the spin-recovery parachute requirements.

The recovery characteristics of the model in its original design were considered to be unsatisfactory inasmuch as recovery from the flatter of two types of spin, indicated as possible, was sometimes slow. Installation of a large ventral fin eliminated the flat spin and made the recovery characteristics of the model satisfactory. Varying stabilizer incidence, extending slats, or removing the stall-control vanes had little effect on the spin and recovery characteristics. Tests and analysis indicate that a 6.8-foot-diameter hemispherical tail parachute with a drag coefficient of approximately 1.17 (based on projected area of hemispherical canopy) or an 11-foot-diameter flat tail parachute with a drag coefficient of 0.65 (based on area of flat canopy) would be satisfactory as an emergency spin-recovery device.

INTRODUCTION

An investigation was conducted in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a $\frac{1}{25}$-scale model of the Douglas D-558-II airplane. The airplane is a single-place, rocket-propelled, transonic research airplane.

The erect and inverted spin and recovery characteristics were determined for the model in the normal design gross weight loading, clean condition. The effects on the spin and recovery characteristics of varying the stabilizer incidence, extending the slats, and removing the stall-control vanes were also determined. Two sizes of ventral fins were tested in an attempt to improve the spin and recovery characteristics of the model and the effects of tail and wing-tip parachutes as devices for emergency recovery from the spin were investigated.

SYMBOLS

b	wing span, feet
S	wing area, square feet
$\bar{c}$	mean aerodynamic chord, feet
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below fuselage reference line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes respectively, slug-feet^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter

ρ	air density, slugs per cubic foot
μ	relative density of airplane $\left(\frac{m}{\rho Sb}\right)$
α	angle between fuselage reference line and vertical (approx. equal to absolute value of angle of attack at plane of symmetry), degrees
ϕ	angle between span axis and horizontal, degrees
V	full-scale true rate of descent, feet per second
Ω	full-scale angular velocity about spin axis, revolutions per second

APPARATUS AND METHODS

Model

The $\frac{1}{25}$-scale model of the Douglas D-558-II airplane was received and was checked for dimensional accuracy and prepared for testing by the Langley Laboratory. A three-view drawing of the model is shown in figure 1 and a photograph of the model is presented in figure 2. Dimensional characteristics of the airplane represented by the model are given in table I. The values in table II for unshielded rudder volume coefficient, tail-damping ratio, and tail-damping power factor were computed by the method of reference 1. Figure 3 is a sketch showing the dimensions and location of the wing slats tested on the model and figure 4 shows sketches of the ventral fins that were installed on the model for some of the tests. The stall-control vanes installed on the model were an integral part of the airplane design and, unless otherwise indicated, were on the wing of the model for all spin tests.

The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet (ρ = 0.001496 slug per cu ft). The weight, moments of inertia, and center-of-gravity location of the airplane were obtained from data furnished by the Douglas Aircraft Company. A remote-control mechanism was installed in the model to actuate the rudder or open the parachute for recovery attempts. Sufficient hinge moment was applied to the rudder during the recovery tests to move it fully and rapidly to the desired position.

Both conventional flat-type silk parachutes (porosity approx. 120) and a hemispherical-type high-porosity nylon stable parachute (porosity 400) were used in the model tests; the porosity of the parachute is based on the cubic feet of air that will pass through one square foot of the cloth per minute under a pressure of one-half inch of water. Drag coefficients of the parachutes were measured at the time of the tests.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel except that the models are launched by hand with spinning rotation into the vertically rising air stream rather than being launched by spindle. The airspeed is adjusted until the drag of the model balances the weight and, after a number of turns in the established spin, recovery is attempted by moving one or more controls by means of the remote-control mechanism. After recovery, the model dives into a safety net. The model is retrieved, the controls reset, and the model is then ready for the next spin. A photograph of the D-558-II model spinning in the test section of the tunnel is shown as figure 5.

The spin data presented herein were obtained and converted to corresponding full-scale values by methods described in reference 2. The turns for recovery were measured from the time the controls were moved or the parachute was opened to the time the spin rotation ceased and the model dived into the net. For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery does not necessarily indicate an improvement over a >8-turn recovery. For recovery attempts in which the model did not recover in less than 10 turns, the recovery was recorded as ∞. When the model did not spin but recovered without control movement with the controls set with the spin, the result was recorded as "no spin."

In accordance with the standard free-spinning-tunnel test procedure, tests were made to determine the spin and recovery characteristics of the model at the normal spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations including zero and maximum settings of the surfaces for various model configurations. Recovery was generally attempted by rapid full rudder reversal. As is customary, tests were also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator was set at two-thirds of its full-up deflection and the ailerons were set at one-third of full deflection in the direction conducive to slower recoveries (against the spin for the D-558-II model). Recovery was attempted by rapidly reversing the rudder from full with to only two-thirds against the spin. This particular control configuration and manipulation is referred to as the "criterion spin." Recovery characteristics of the model are considered satisfactory if recovery from this criterion spin requires $2\frac{1}{4}$ turns or less; this value has been selected on the basis of full-scale airplane spin-recovery data that are available for comparison with corresponding model test results.

The testing technique for determining the optimum size of and the towline length for spin-recovery parachutes is described in detail in reference 3. For the tail-parachute tests, the towline was attached to the model at the plane of symmetry under the back end of the fuselage. For the wing-tip parachute tests, the towline was attached to the outboard wing tip (right tip for left spins), the towline length being such that the fully open parachute would just miss the horizontal tail, and the parachute was packed on the wing. The tail parachute and the wing parachute were placed on the fuselage or wing, respectively, in such a position that it did not appreciably influence the steady spin before the parachute was opened. It is recommended that the parachute be packed within the wing for a full-scale wing-parachute installation, and that any full-scale parachute installation be provided with a positive means of ejection. For the current model tests, the rudder was held with the spin during attempted recoveries so that the test results were due entirely to the effect of opening the parachute.

PRECISION

The model test results presented herein are believed to be the true values given by the model within the following limits:

α, degrees	±1
ϕ, degrees	±1
V, percent	±5
Ω, percent	±2
Turns for recovery:	
From motion-picture records	$\pm\frac{1}{4}$

The preceding limits may have been exceeded for certain spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and airplane spin results (references 2 and 4) indicates that spin-tunnel results are not always in complete agreement with airplane results. In general, the models spun at a somewhat smaller angle of attack, at a somewhat higher rate of descent, and with 5° to 10° more outward sideslip than did the corresponding airplanes. The comparison made in reference 4 for 21 airplanes showed that 16 of the models predicted satisfactorily the corresponding airplane recovery characteristics and that 2 of them overestimated and that 3 of them underestimated the corresponding number of turns for recovery.

Based on the data presented in reference 5, it appears that good correlation exists between model and full-scale spin recoveries effected by tail parachute. No comparable full-scale data exist for wing parachutes.

Because of the impracticability of ballasting the model exactly and because of inadvertent damage to the model during the spin tests, the measured weight and mass distribution of the model varied from the true scaled-down values. The following table shows the range of weight and mass distribution variations measured for the model:

Weight, percent	1 low to 0
Center-of-gravity location, percent $\bar{c}$	0 to 1 rearward
Moments of inertia:	
I_X, percent	0 to 6 high
I_Y, percent	0 to 5 high
I_Z, percent	0 to 5 high

The accuracy of measuring the weight and mass distribution of the model is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

The controls were set with an accuracy of $\pm 1^\circ$.

TEST CONDITIONS

The mass characteristics and inertia parameters for loadings possible on the D-558-II airplane and for the loading tested on the model are listed in table III. The inertia parameters for the loadings of the airplane and model are plotted in figure 6. As discussed in reference 6, figure 6 can be used as an aid in predicting the relative effectiveness of the controls on the spin and recovery characteristics of the model.

The maximum control deflections used in the tests were:

Rudder, degrees	25 left, 25 right
Elevator, degrees	25 up, 15 down
Ailerons, degrees	15 up, 15 down

The intermediate control deflections used in the tests were:

Rudder two-thirds deflected, degrees	$16\frac{2}{3}$
Elevator two-thirds up, degrees	$16\frac{2}{3}$
Ailerons one-third deflected, degrees	5 up, 5 down

For all the tests, the landing gear and landing flaps were retracted and the cockpit was closed. For some of the tests, slats were extended or ventral fins were installed.

RESULTS AND DISCUSSION

The spins and recoveries obtained with the model were not similar for left and right spins. In the initial tests, spins to the right were generally steep and recoveries rapid, whereas spins to the left were generally flat and recoveries unsatisfactory. During the test program this asymmetry in the model results reversed itself in direction several times. Measurements and special tests were made in an attempt to determine the cause of the asymmetrical results but no appreciable misalinement of the model or any other cause for the asymmetry was found. Indications are that the asymmetrical results were caused by inadvertent model asymmetry which, although it was too small to be measured, nevertheless affected the results of the current design appreciably. During the course of the investigation a new wing was built for the model and the results of check tests made on the model with the new wing installed were generally similar to those for the original wing. It appears that small variations in the airplane construction, within production tolerances, may also cause the full-scale airplanes to have varying recovery characteristics with the possibility of unsatisfactory recoveries.

The model data are presented in terms of full-scale values for the airplane at a test altitude of 15,000 feet. Unless otherwise stated, all tests were performed with the model in the clean condition (cockpit closed, flaps neutral, landing gear retracted, slats retracted, and stall-control vanes installed).

Erect Spins

Basic clean condition.- The erect spin test results obtained with the model in the normal design gross weight loading for 0° stabilizer incidence are shown in chart 1. The right spins obtained were wide radius, wandering spins which were oscillatory in roll and yaw. Recoveries by rudder reversal were rapid. The left spins obtained were generally flat with gradual oscillations in pitch and an occasional irregular rolling motion. The rolling motion consisted of the outboard wing (right wing in the spin to the left) rolling down between 10° and 20° below horizontal and immediately rolling upward to a few degrees above horizontal and then returning to an approximately level attitude. Recovery characteristics from the left spins were generally unsatisfactory; but for some of the individual recovery attempts for some of the spins, satisfactory results were obtained. It appears that the satisfactory recoveries were associated with the aforementioned rolling motion, in that they occurred when the rudder happened to be reversed just as the outboard wing rolled down. It is also significant that the model occasionally ceased spinning without movement of the controls, following the rolling down motion of the outboard wing. Based on the aforementioned unsatisfactory recoveries, it appears that from certain flat spinning conditions indicated possible on the airplane, reversing the rudder will have no appreciable effect on the spin. The possible ineffectiveness of the rudder was also indicated on the model by a few tests in which the model was launched with spin rotation with the rudder set full against the spin and either a no-spin condition or a flat spin was obtained. Inasmuch as the mass distributions for all loadings indicated as possible on the D-558-II airplane are not appreciably different from those for the normal design gross weight loading tested, it is believed that the spin and recovery characteristics obtained during the model tests for the model in the normal design gross weight loading are generally applicable to the other possible loadings of the airplane.

Because of the unsatisfactory recovery characteristics indicated by the model test results as possible on the D-558-II airplane, intentional spinning of the airplane should be avoided. The unsatisfactory recovery characteristics appear to be contrary to what would be expected from the spin-recovery criterion presented in reference 1. However, the mass distribution in the D-558-II airplane is extremely heavy along the fuselage as compared to the wing and is far beyond the range covered by the empirical criterion in reference 1; therefore the criterion is not directly applicable to the subject airplane. Brief tests were made with the model reballasted so that the inertia parameters fell within the range covered by the criterion of reference 1 $\left(\frac{I_X - I_Y}{mb^2} = -300 \times 10^{-4}\right)$ and the recoveries were satisfactory for this condition.

Effect of varied stabilizer incidence.- The results of brief tests (data not presented in chart form) in which the model stabilizer incidence was set at 4° leading edge up and 6° leading edge down (from fuselage reference line) generally were similar to those obtained with 0° stabilizer incidence as shown in chart 1.

Effect of slats.– For the investigation of the effects of slats on the spin and recovery characteristics of the model, the previously discussed asymmetrical characteristics had reversed and steep spins and generally rapid recoveries were obtained with the model in the basic clean condition for left spins. The results of tests of the model for the steep left spins both in the basic clean condition and with the slats extended are presented in chart 2. Extending the slats had only a slight beneficial effect in that recoveries were somewhat more rapid. Brief tests of the model for flat spins (results not presented) showed no appreciable effect of extending the slats on the spin and recovery characteristics of the model.

Effect of stall-control vanes.– The results of brief tests indicated that removing the stall-control vanes on the wing of the model had no effect on the spin and recovery characteristics of the model.

Effect of ventral fins.– The results of tests made in an attempt to improve the spin and recovery characteristics of the model by the addition of a ventral fin are presented in table IV. Because the flat spins and poor recoveries discussed previously (chart 1) were difficult to obtain regularly, at this point in the test program the model was purposely misalined in order to obtain flat spins and poor recoveries similar to those presented in chart 1, and the effect of adding a ventral fin was then determined from this adverse condition. Two sizes of ventral fins were investigated. The addition of a small ventral fin (ventral fin no. 1 in fig. 4) had little effect on recoveries, the results being similar to those obtained with the model in the clean condition. The addition of a larger ventral fin (ventral fin no. 2 in fig. 4), however, eliminated the flat spins and led to recoveries which were satisfactory.

Inverted Spins

The model would not spin in an inverted attitude either to the right or to the left when the rudder was held full with the spin and the ailerons and elevator were neutral. Although the recovery characteristics were not investigated for other control configurations, an analysis of the results of spin tests of other similar models indicates that the D-558-II airplane should recover satisfactorily from an inverted spin by reversing the rudder and neutralizing the stick both laterally and longitudinally.

Landing Condition

The landing condition was not tested on the model. An analysis of full-scale and model tests indicates that the extension of flaps usually has an adverse effect on recovery characteristics (reference 7) and although the D-558-II airplane will probably recover satisfactorily from an incipient spin in the landing condition, recoveries from fully developed spins will be unsatisfactory. It is recommended therefore that recovery be attempted and the flaps be neutralized immediately upon entering an inadvertent spin in the landing condition in order to insure that transition from the incipient to the fully developed spin does not take place.

Spin-Recovery Parachute Tests

Even though it was understood that for the D-558-II airplane the normal spin demonstration in flight was waived, tests were conducted to determine the optimum size parachutes that would be needed as an emergency device to effect recoveries from uncontrollable spins. The test results obtained with spin-recovery parachutes are presented in table V. The recovery attempts were made from a spin that was flat and from which recoveries by rudder reversal were unsatisfactory (elevator neutral, ailerons neutral; see chart 1). The test results indicated that a conventional flat-type unstable parachute 11 feet in diameter (full-scale) with a drag coefficient of approximately 0.65 (based on area of flat canopy) or a hemispherical high-porosity stable parachute 8.85 feet in diameter (full-scale) with a drag coefficient of approximately 1.17 (based on projected area of hemispherical canopy) would provide satisfactory recovery by parachute action alone if opened from the tail of the airplane on the end of a towline of the order of 50.5 feet and 37.5 feet (full-scale) long, respectively. The aforementioned 8.85-foot-diameter (full-scale) parachute was the smallest hemispherical-type parachute available when the tests were made. Reference 8 indicates that for porosities up to 400, a hemispherical tail parachute which provides approximately 70 percent of the drag of a conventional flat-type tail parachute will give spin recoveries similar to those obtained with the flat-type parachute, and on this basis a 6.8-foot-diameter hemispherical parachute with a drag coefficient of approximately 1.17 would probably be effective as an emergency spin-recovery device. As pointed out in reference 8, the principal advantage of using a stable parachute is that during level flight check runs they do not cause violent pitching and yawing gyrations of the airplane as do unstable tail parachutes. Additional test results (data unpublished) have indicated that parachute opening, stability, and drag characteristics may vary with velocity; therefore, it is recommended that before a parachute selected as a spin-recovery device is put to practical use it should be tested at airspeeds similar to those encountered in spins to make sure that it will open in the air stream and that it has suitable drag and stability characteristics.

Neither of the two wing-tip parachutes tested (6.25- and 8.35-foot-diameter flat parachutes, full-scale) led to a satisfactory spin recovery because the towline length was restricted. Longer towlines or larger wing-tip parachutes could not be used in the present tests because of the nearness of the sweptback-wing tips to the tail surfaces and subsequent probability of fouling the tail surfaces. After the pack was opened, the parachute appeared to be in the wake of the outboard wing and, alternately, inflated and collapsed on the wing even though it was clear at times. This result is in agreement with those of reference 9, wherein it is indicated that the wake effect behind a stalled wing may prevent a wing-tip parachute from opening if the towline is short.

Control Forces

The discussion of the results so far has been based on control effectiveness alone without regard to the forces required to move the controls. For all tests, sufficient force was applied to the model rudder to move it fully and rapidly. Sufficient force must be applied to the airplane rudder control to move it in a similar manner in order for the model and airplane results to be comparable. Based on the data presented in reference 10 an estimation of the force required to reverse the rudder fully and rapidly against the spin was made, and it was found that the force would be small (under 75 lb) and well within the capabilities of a pilot.

Recommended Recovery Technique

Based on the results obtained with the model and upon general spin-tunnel experience, the following recommendations are made regarding spinning for all loadings and conditions of the D-558-II airplane: Intentional spinning should be avoided. If, however, a spin is inadvertently entered, corrective controls should be applied immediately. For erect spins, the rudder should be reversed briskly to oppose the spin rotation followed immediately by movement of the stick to laterally neutral and forward far enough to effect the recovery dive; care should be exercised to avoid excessive accelerations in the recovery dive and pull-out. If flaps are extended, they should be immediately neutralized and recovery attempted. If spin rotation is encountered while in an inverted attitude, the rudder should be reversed briskly to oppose the rotation and the stick moved to neutral (laterally and longitudinally).

CONCLUSIONS AND RECOMMENDATIONS

Based on results of spin tests of a $\frac{1}{25}$-scale model of the Douglas D-558-II airplane, the following conclusions and recommendations regarding spin and recovery characteristics of the airplane at an altitude of 15,000 feet are made:

1. The critical nature of the design with regards to spin recovery may make recoveries from fully developed flat spins unsatisfactory and therefore intentional spins should be avoided.

2. Recovery should be attempted immediately upon entering an inadvertent spin. For recovery from erect spins, the rudder should be reversed fully and rapidly and then followed immediately by movement of the stick to laterally neutral and forward of neutral.

3. Satisfactory recoveries from any inverted spin that may be obtained will be possible by reversing the rudder and neutralizing the stick.

4. The rudder-control force encountered in a spin will be well within the capabilities of the pilot.

5. If a spin is inadvertently entered in the landing condition or with just the flaps extended, the flaps should be neutralized and recovery should be attempted immediately.

6. Varying the stabilizer incidence from 4° leading edge up to 6° leading edge down, opening the wing slats, or removing the stall-control vanes will have no appreciable effect on the spin and recovery characteristics.

7. Installation of a large ventral fin will lead to satisfactory recovery characteristics.

8. A 6.8-foot-diameter hemispherical tail parachute with a drag coefficient of approximately 1.17 (based on projected area of hemispherical canopy) or an 11-foot-diameter flat tail parachute with a drag coefficient of approximately 0.65 (based on area of flat canopy) will be a satisfactory emergency device for effecting recovery from an uncontrollable spin.

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TABLE I.– FULL-SCALE DIMENSIONAL CHARACTERISTICS OF THE DOUGLAS D-558-II AIRPLANE AS REPRESENTED BY THE $\frac{1}{25}$-SCALE MODEL

Fuselage length, ft	44.50
Wing:	
Span, ft	25.00
Area, sq ft	175.00
Section, root	NACA 63_1-010
Section, tip	NACA 63_1-012
Root chord incidence, deg	3
Tip chord incidence, deg	3
Aspect ratio	3.6
Sweepback of wing 30 percent chord, deg	35
Dihedral, deg	-3
Mean aerodynamic chord length, in.	87.301
Leading edge of mean aerodynamic chord rearward of leading edge of wing at airplane center line, in.	54.125
Ailerons:	
Chord (rearward of hinge line) percent of wing chord	15.0
Area (rearward of hinge line) percent of wing area	5.6
Span, percent of wing semispan	45.3
Horizontal tail surfaces:	
Total area, sq ft	39.90
Elevator area (rearward of hinge line), sq ft	9.48
Distance from center of gravity to elevator hinge line at plane of symmetry for normal design gross weight loading, ft	19.61
Vertical tail surfaces:	
Total area, sq ft	32.99
Rudder area (rearward of hinge line), sq ft	6.15
Distance from center of gravity to rudder hinge line at base for normal design gross weight loading, ft	19.41

TABLE II.- TAIL-DAMPING POWER FACTORS FOR THE VARIOUS TAIL CONFIGURATIONS TESTED ON THE $\frac{1}{25}$-SCALE MODEL OF THE DOUGLAS D-558-II AIRPLANE

Tail configuration	TDR	URVC	TDPF
Original	0.2645	0.0333	$8,808 \times 10^{-6}$
Ventral fin no. 1 installed	.3113	.0333	10,366
Ventral fin no. 2 installed	.3524	.0333	11,735

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TABLE III.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADING CONDITIONS POSSIBLE ON THE DOUGLAS D-558-II AIRPLANE AND FOR THE LOADING TESTED ON THE $\frac{1}{25}$-SCALE MODEL

[Model values converted to corresponding full-scale values; moments of inertia are given about center of gravity]

No.	Loading	Weight	Airplane relative density		Center of gravity		Moments of inertia (slug-ft^2)			Inertia parameters		
			Sea level	15,000 feet	$x/\bar{c}$	$z/\bar{c}$	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
	Airplane values											
1	Normal design gross weight	11,250	33.6	53.3	0.205	0.026	2895	29,331	30,849	-1211×10^{-4}	-70×10^{-4}	1281×10^{-4}
2	Nose-heavy design gross weight	11,250	33.6	53.3	.159	-.03	2900	29,295	30,806	-1209	-69	1278
3	Tail-heavy design gross weight	11,250	33.6	53.3	.248	-.03	2891	29,254	30,774	-1207	-70	1277
4	Normal gross weight; 250 gal gasoline and 1/2 rocket fuel	11,569	34.5	54.9	.202	-.03	2966	27,380	28,877	-1087	-67	1154
5	Overload gross weight; 250 gal gasoline and full rocket fuel	13,139	39.2	62.3	.200	-.05	3058	30,348	31,816	-1070	-58	1128
	Model values											
1	Normal design gross weight	11,182	33.4	53.0	0.205	-0.01	3024	30,167	32,158	-1252	-92	1344

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TABLE IV.– EFFECT OF VENTRAL FINS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{25}$-SCALE MODEL OF THE DOUGLAS D-558–II AIRPLANE

[Normal design gross weight loading, stall-control vanes installed, slats retracted; stabilizer incidence 4° leading edge up (recovery attempted from and steady-spin data presented for rudder full-with spins); right erect spins]

	Normal condition (no ventral installed)			Ventral fin no. 1 installed (see fig. 4)	Ventral fin no. 2 installed (see fig. 4)	
Ailerons	1/3 against	Neutral		1/3 against	1/3 against	Neutral
Elevator	2/3 up	^{a}Up		^{c}2/3 up	^{c}2/3 up	Up
α, deg		^{b}54	No spin	38 to 49	35 to 56	
ϕ, deg		^{b}3D to 15U		8D to 3U	5D to 15U	
Ω, rps	0.197	0.197		0.196		
V, fps	249	249		249	270	270
Turns for recovery	$^{d}{>}5$, $^{d}{>}8$, $^{d}{>}8$	>4, $\frac{1}{2}$, ∞, >3		$^{d}3\frac{1}{2}$, $^{d}{>}2$, $^{d}{>}3$, $^{d}{>}9$	$^{d}\frac{1}{2}$, $^{d}\frac{3}{4}$, $^{d}1$, $^{d}\frac{1}{2}$	$\frac{1}{2}$, $1\frac{1}{2}$, 1

[a] Two conditions possible.
[b] Oscillatory spin, range of values or average value given.
[c] Wandering and oscillatory spin, range of values or average value given.
[d] Recovery attempted by reversing the rudder from full with to 2/3 against the spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

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TABLE V.– SPIN-RECOVERY-PARACHUTE DATA OBTAINED WITH THE $\frac{1}{25}$-SCALE MODEL OF THE DOUGLAS D-558-II AIRPLANE

[Left spins; ailerons neutral, elevator neutral; normal design gross weight loading, slats retracted, stall-control vanes installed; recoveries attempted from established spins; rudder held with the spin]

Parachute data						Turns for recovery
Type	Diameter feet	Number of shroud lines	Shroud line length to parachute diameter ratio	Towline length, feet	[a]Drag coefficient	
Tail parachutes						
Hemis-pherical	8.85	12	2.59	37.5	Approx. 1.17	$1, 1, \frac{1}{4}, 1\frac{1}{4}, 1\frac{1}{4}$
Flat	11	8	1.32	50.5	Approx. .65	$1\frac{1}{2}, 2, \frac{1}{2}, 1\frac{1}{4}, 1\frac{1}{4}$
Flat	10	8	1.33	55.2	Approx. .65	$\frac{1}{2}, >4, 1\frac{1}{2}, 1\frac{1}{4}, \frac{3}{4}, 1, >6, 1\frac{1}{2}$
Wing-tip parachutes						
Flat	6.25	8	1.25	4.16	Approx. 0.65	4, 8
Flat	8.35	8	1.50	0	Approx. .47	7, 10

[a] Based on surface area for flat-type parachute and on projected area for hemispherical-type parachute.

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CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{25}$-SCALE MODEL OF THE DOUGLAS D-558 - II AIRPLANE

[Normal design gross weight loading; slats retracted; stall control vanes installed; horizontal tail incidence 0°; steady-spin data presented for and recovery attempted from rudder-full-with spins; recovery attempted by rapid full rudder reversal except as noted]

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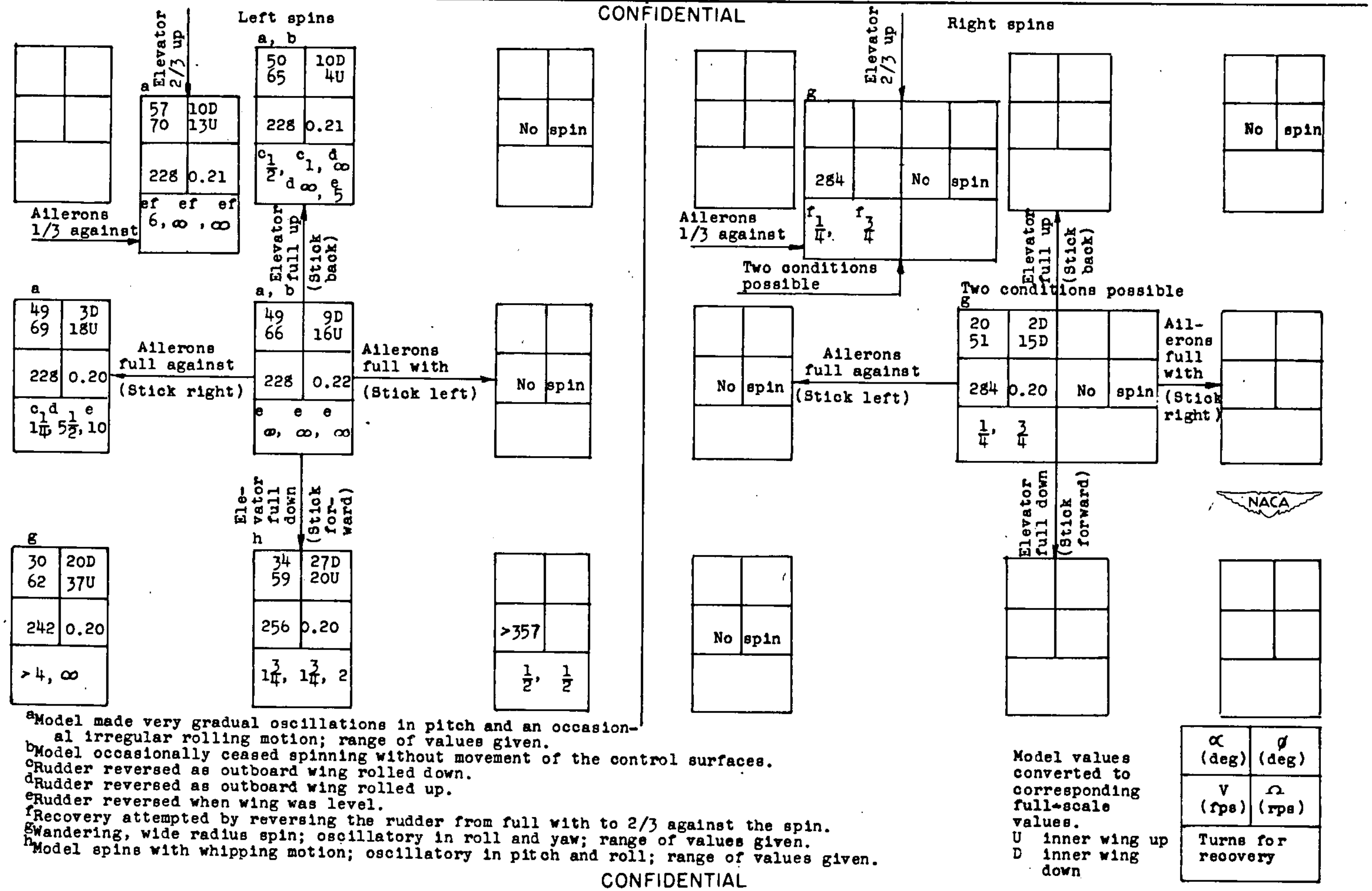

[a] Model made very gradual oscillations in pitch and an occasional irregular rolling motion; range of values given.

[b] Model occasionally ceased spinning without movement of the control surfaces.

[c] Rudder reversed as outboard wing rolled down.

[d] Rudder reversed as outboard wing rolled up.

[e] Rudder reversed when wing was level.

[f] Recovery attempted by reversing the rudder from full with to 2/3 against the spin.

[g] Wandering, wide radius spin; oscillatory in roll and yaw; range of values given.

[h] Model spins with whipping motion; oscillatory in pitch and roll; range of values given.

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CHART 2.- EFFECTS OF EXTENDING SLATS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{25}$-SCALE MODEL OF THE DOUGLAS D-558 - II AIRPLANE

[Normal design gross weight loading; stall control vanes installed; horizontal tail incidence leading edge 6° down; left erect spins; steady-spin data presented for and recovery attempted from rudder-full-with spins; recovery attempted by rapid full rudder reversal except as noted]

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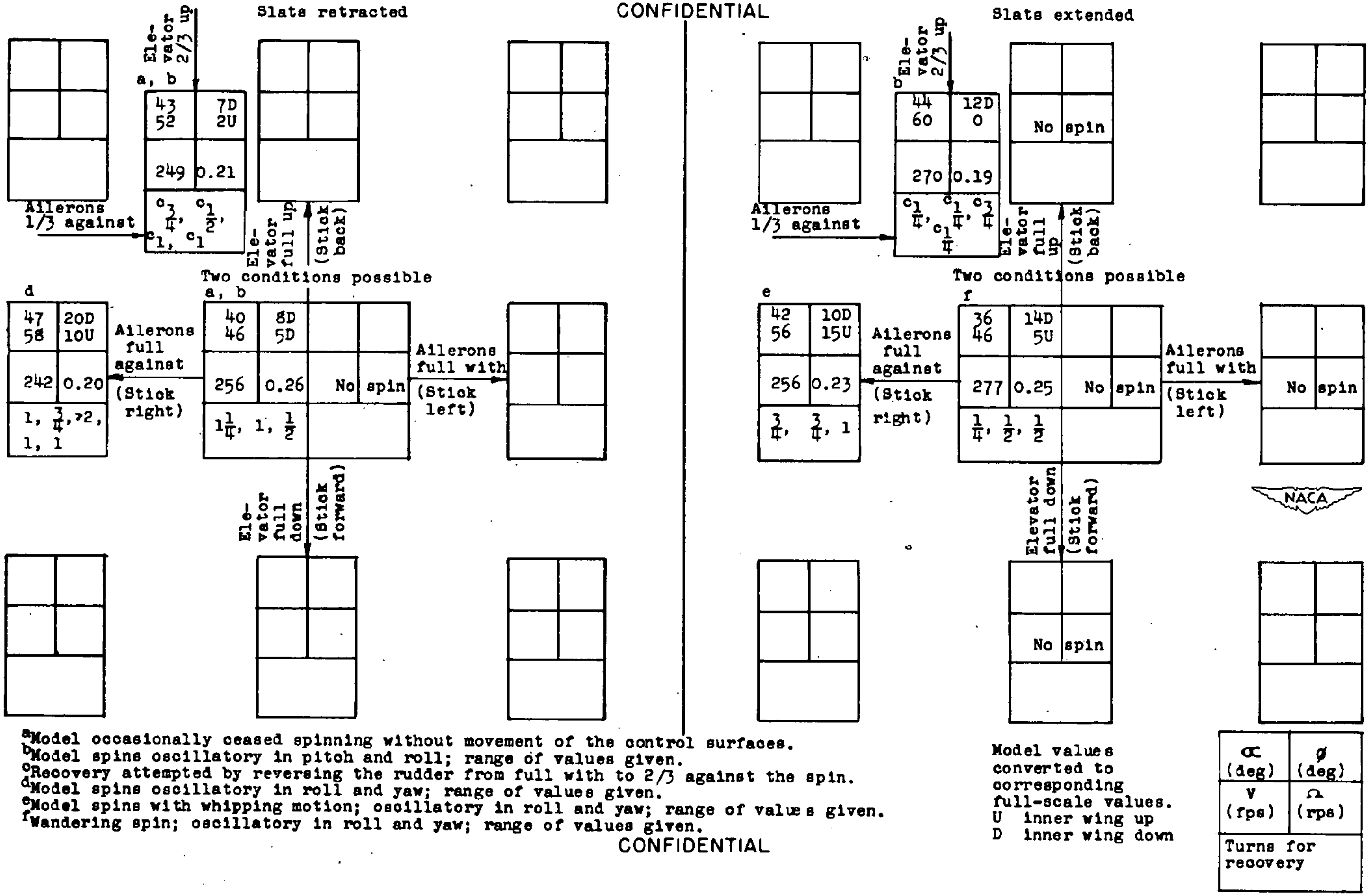

[a]Model occasionally ceased spinning without movement of the control surfaces.
[b]Model spins oscillatory in pitch and roll; range of values given.
[c]Recovery attempted by reversing the rudder from full with to 2/3 against the spin.
[d]Model spins oscillatory in roll and yaw; range of values given.
[e]Model spins with whipping motion; oscillatory in roll and yaw; range of values given.
[f]Wandering spin; oscillatory in roll and yaw; range of values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

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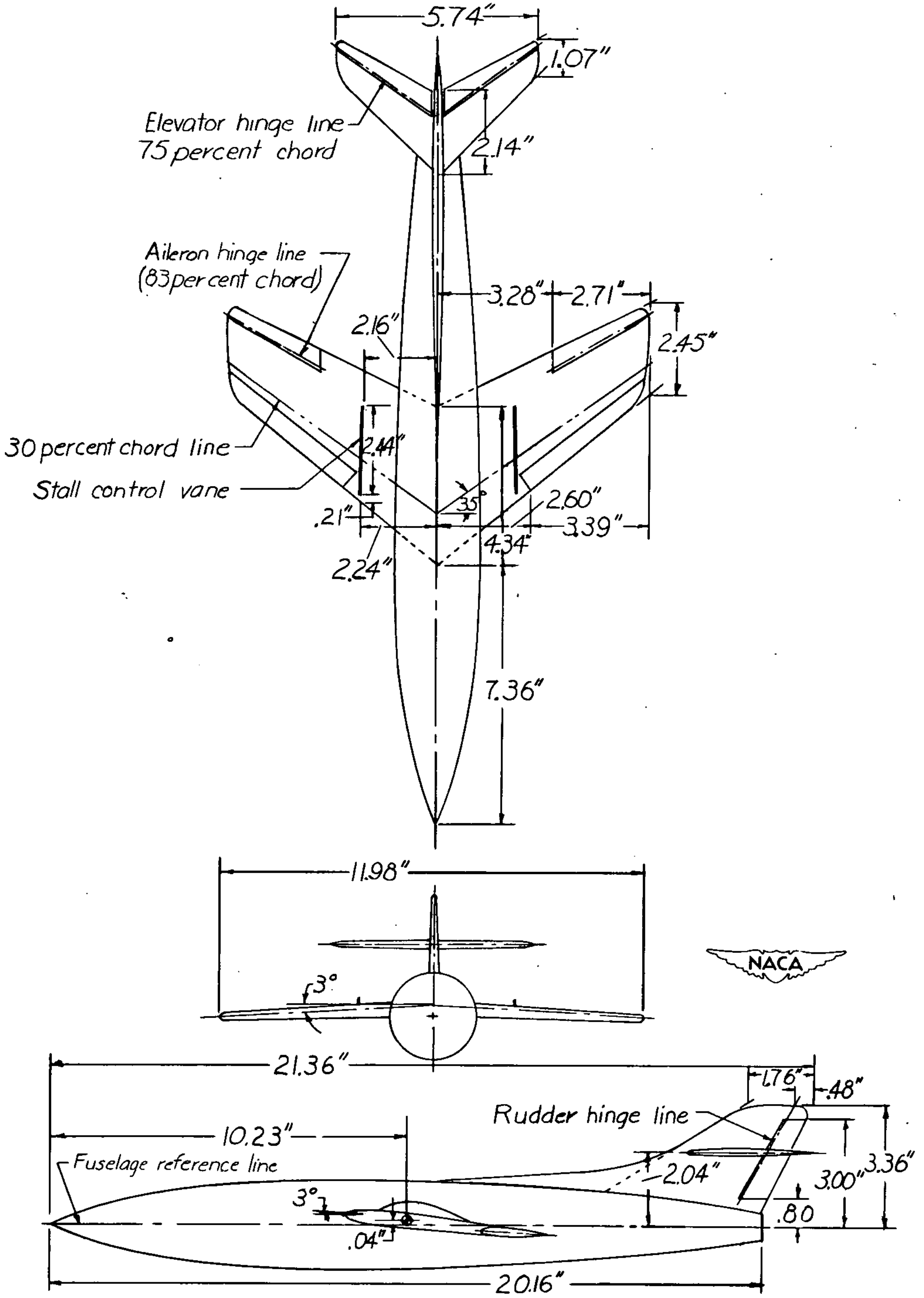

Figure 1.- Three-view drawing of the $\frac{1}{25}$-scale model of the Douglas D-558-II airplane as tested in the Langley 20-foot free-spinning tunnel. Center of gravity is shown for normal gross weight condition. Dimensions are model values.

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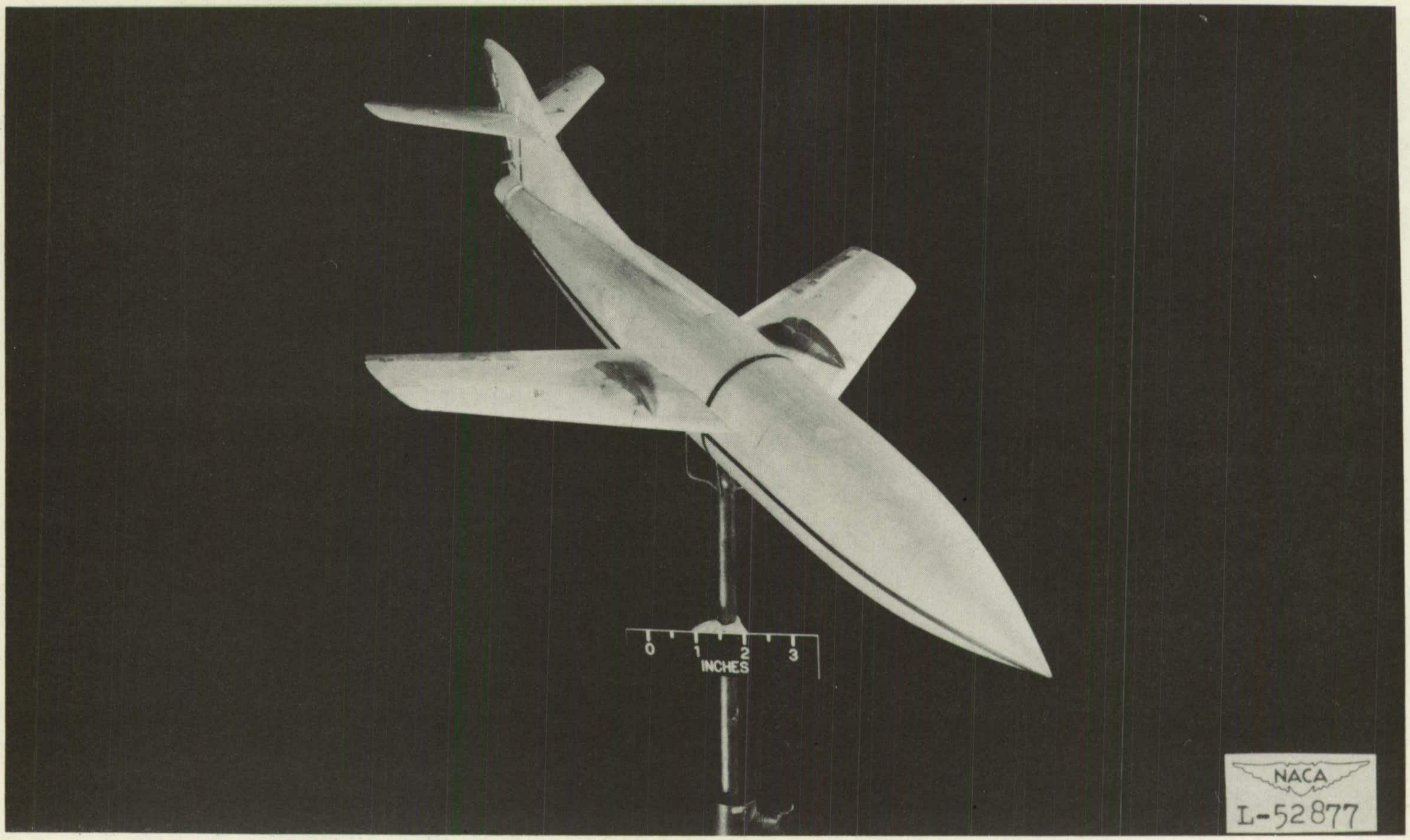

Figure 2.- The $\frac{1}{25}$-scale model of the Douglas D-558-II airplane tested in the Langley 20-foot free-spinning tunnel.

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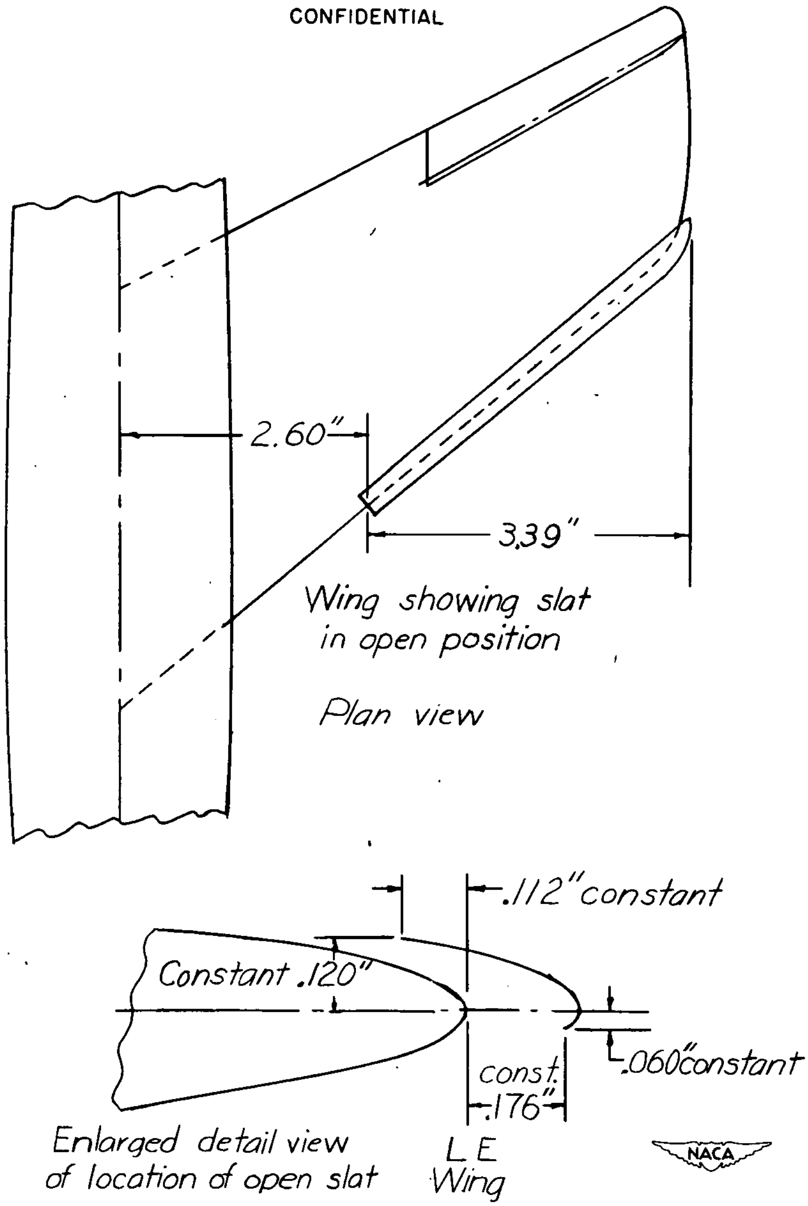

Figure 3.- Sketch showing location and dimensions of open wing slats tested on the $\frac{1}{25}$-scale model of the D-558-II airplane in the free-spinning tunnel. **CONFIDENTIAL**

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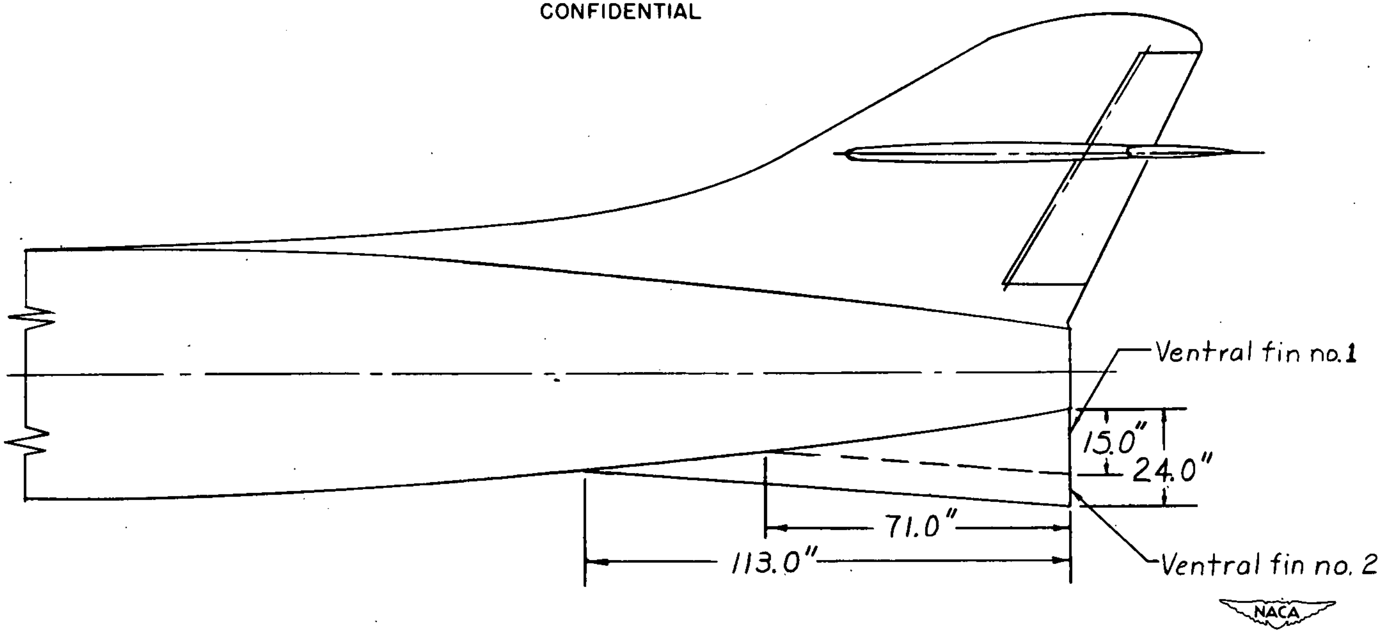

Figure 4.- Sketch of the ventral fins tested on the $\frac{1}{25}$-scale model of the Douglas D-558-II airplane in the free-spinning tunnel (dimensions are full-scale values).

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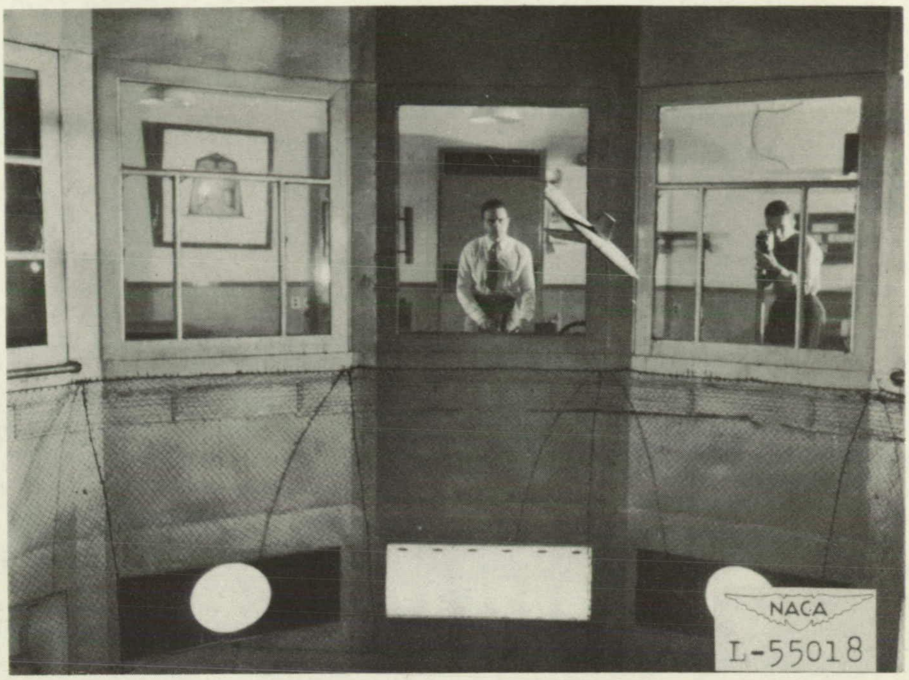

Figure 5.- The $\frac{1}{25}$-scale model of the Douglas D-558-II airplane spinning in the Langley 20-foot free-spinning tunnel.

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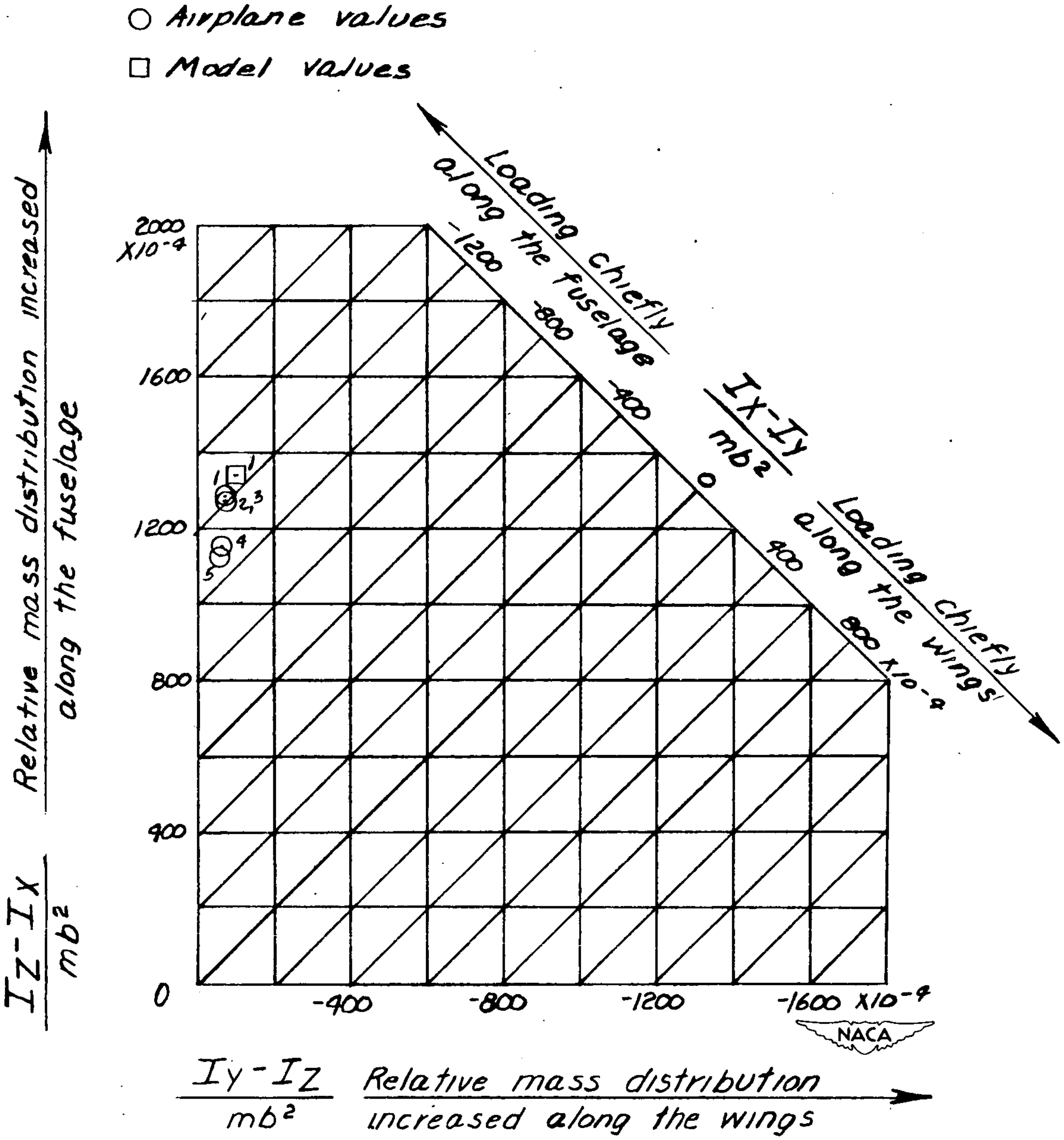

Figure 6.- Inertia parameters for loadings possible on the D-558-II airplane and for the loading used on the $\frac{1}{25}$-scale model. (Points are for loadings listed in table III.)